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ABSTRACT

There is widespread acceptance that teaching from a constructivist paradigm requires a learning environment, a set of teaching-learning strategies, and a method of assessment that differs significantly from those usually found in classrooms that operate from a behaviorist theory or from an objectivist epistemology. There is, however, less unanimity about the nature of a constructivist paradigm, how the paradigm can be interpreted to create a teaching-learning environment that operates from a constructivist perspective, or whether the teaching-learning process that operates from a constructivist perspective is a prime example of "pedagogical tricks" in action. This paper records an interactive symposium addressing the question of whether teaching from a constructivist perspective should be considered a case of "pedagogical tricks". Contributors to this discussion address these issues by presenting their individual perspectives in their own voices rather than synthesizing individual perspectives into a conceptual whole. A brief synopsis of participant research interests is included to help the reader put the participants' comments into context. Contains 48 references. (PVD)

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ED 407 269

TEACHING FROM A CONSTRUCTIVIST PARADIGM: A WAY OF KNOWING AND LEARNING OR A CASE OF "PEDAGOGICAL TRICKS?"

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An Interactive Discussion presented at the Annual Meeting of the National Association for Research in Science Teaching, St. Louis, MO, April, 1996

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Introduction

There is wide spread acceptance that teaching from a constructivist paradigm requires a learning environment, a set of teaching-learning strategies, and a method of assessment that differs significantly from those usually found in classrooms that operate from a behaviorist theory of mind and learning, or an objectivist epistemology. There is, however, far less unanimity about the nature of a constructivist paradigm, how the paradigm can be interpreted to create a teaching-learning environment that operates from a constructivist perspective, or whether the teaching-learning process that operates from a constructivist perspective is prime example of "pedagogical tricks" in action. This then leads directly to the topic of this paper: Should teaching from a constructivist perspective be considered a case of "pedagogical tricks?"

We pose this question for three reasons. First, during an Interactive Symposium presented at the Annual Meeting of the National Association for Research in Science Teaching, San Francisco, April, 1995 the issue of "pedagogical trick" was raised by Reinders Duit from the IPN-Institute for Science Education at the University of Kiel and was subsequently discussed by several members participating in the interactive symposium. At this venue, reactions from those in attendance indicated a keen interest in the topic. Second, we pose this question because we value teaching that addresses student thinking, supports student conceptual understanding and intellectual development, and would like to discuss the meaning of establishing a classroom environment that fosters teaching-learning with students' ideas in mind (Hewson, Bell, Grimellini Tomasini and Pecori Balandi, Hennessey, & Zietsman, 1995; Beeth, 1995). Lastly, we pose this question because we realize that techniques employed, by classroom practitioners, to become aware of students' thinking, teaching sequences aimed at planning classroom work from a constructivist perspective, or the methods employed to structure and re-structure students' thinking can, under certain circumstances, become a set of "pedagogical tricks."

In the process of reflecting on the topic of this paper several issues emerged which appear, to us, to be significant. These issues are:

- the nature of constructivist paradigm;
- implications of a constructivist paradigm for the teaching-learning process: a constructivist pedagogy; and
- the nature of "pedagogical tricks."

We contend that dialectic discussion about the above issues have the potential to result in new constructions with which the participants can agree, not because the new constructions are "truer" than other of its predecessors but because it is better informed and more sophisticated. It is our earnest interest during this interactive round table discussion to work towards that goal.

Contributors

As contributors to this round table discussion, we have chosen to address the above issues by presenting our individual perspectives in our own voice. Rather than attempting to synthesize each of our perspectives in to a conceptual whole-- by accenting the commonalities and minimizing the differences-- we have chosen instead to preserve, as much as possible, the different context from which we respond to the above issues. We have done this not because there are no commonalities upon which we can agree, on the contrary we share considerable commonalities, but because we believe that the context in which each our response are framed is a significantly factor that should be preserved. The context from which we frame our responses include: different expertise in science (Some of us have expertise in the physical sciences, others in the biological or the medical sciences.); different community of learners with which we daily work (Our range extends from elementary students through university students to the professional teaching community.); and a different research focus (Some of us do research with the student we teach, others work with students that someone else is in the process of teaching, while, on occasions, some of us work with science teachers rather than with students.) In spite of this diversity, we share a common background in the topic of this round table discussion, having written about the implications of the constructivist paradigm for teaching of science. Our research has been involved with students' ideas, students' ability to be metacognitive (Hewson & Hennessey, 1992; Hennessey, 1993; 1994b; Beeth, 1993b), teaching that takes students' ideas into consideration (Clement, Brown, & Zietsman, 1989; Zietsman & Clement, 1993; Beeth, 1993a; Hennessey & Beeth, 1993; Hewson & Beeth, 1995), with classroom teachers who are considering developing a constructivist pedagogy (Jones & Beeth, 1995; Beeth & Hennessey, 1996), and with curricular implications of a constructivist approach to the teaching-learning process (Beeth, 1995; Hennessey, 1994a; Hewson, Beeth & Thorley, 1996). A brief synopsis of each our research interests is provide to help contextualize, for the reader, our comments.

MICHAEL E. BEETH

Michael Beeth has taught both biology and chemistry at the secondary level and is currently an assistant professor in the College of Education Department of Educational Theory and Practice at The Ohio State University. Over the past few years he has carried out year long classroom-based research in both elementary and high school science classrooms that documented the metacognitive abilities of students and the impact of these abilities on understanding science concepts. As part of his research, he documented changes in the practices and thinking of one teacher as she learned to implement principles of constructivist teaching in her science classroom. His interests include investigating relationships between the role of the teacher, the role of the student, and the delivery of instruction designed to address conceptual change teaching and learning for both experienced and inexperienced teachers. From a constructivist perspective he sees education in science as a continuous process of conceptual change requiring a long-term intervention that should be dealt with consistently from the elementary to university level. He also believes that conceptual change processes are involved in the training of teachers and that the constructivist perspective may be usefully adopted in designing and developing effective models for teacher training.

ALETTA ZIETSMAN

Aletta Zietsman has taught physics at both secondary and tertiary levels and is currently teaching introductory physics at the University of Witwatersrand, Johannesburg, South Africa where she particularly works with students who have come from school systems with inadequate resources and poorly qualified teachers. In her current position she is involved in a program that focuses on developing students' conceptual understanding. The program concentrates on the qualitative analysis of physics problems and situations and requires more time spend on developing conceptions and less on qualitative problem-solving, a reversal of traditional emphases. Her research has focused on understanding students' thinking in order to develop teaching activities that build on the details of students' current knowledge. Her two research goals are: first, to find anchors, those intuitive ideas about physics that are compatible with those of a physicist, in which to ground instruction; and second, to facilitate conceptual change by focusing on the nature of the reasoning processes that help students construct new conceptual structures. Her research has shown that students often have very useful physical intuitions. Such physical intuitions, that are in agreement with sound physics

principles, can be incorporated into instruction. She has also investigated the non-formal reasoning processes used spontaneously by students in different domains in physics. This has produced data about the nature of the processes through which students have constructed conceptions compatible with those of physicists, using their physical intuitions (anchors). For example, in dealing with lever, symmetry is a powerful anchor for most students. In addition to the anchor, students are able to use extreme case reasoning to reason about different lever types and different physical situations involving levers. The anchors and extreme case reasoning ideas are incorporated into instruction.

M. GERTRUDE HENNESSEY

Sister Gertrude Hennessey teaches science and does research in an elementary school (grades 1-6). The opportunity to work with the same cohort of students over a six year period has provided her with many insights into the intellectual potential of students of this age as well as the freedom to develop coherent, integrated curriculum. Her goals as a researcher are to: describe the significant role metacognition plays in facilitating or promoting conceptual development in young students; and describe the role of explanatory models (i.e., models that represent student thinking) in shaping/ re-shaping students' thinking and theory development. For her, teaching and learning for conceptual understanding requires a learning environment that depends on the delicate inter-weaving of several components, such as: the creation of a classroom climate in which students can express divergent views without sanction; the elicitation and discussion of students' existing views about the science topics under consideration; the implementation of both status-lowering and status-raising activities; the promotion of metacognitive component (i.e., an inner awareness or ability to reflect on what one knows and how one knows it--in other words, the ability to think about one's own thinking as an object of cognition) into classroom exploration, dialogue, and discourse; a conceptual understanding on the part of the students for the nature of knowledge production, the nature of science as an enterprise, the nature of conceptual models, and their subsequent role in building explanatory understanding. Her research has produced claims that a learning environment of this nature allows students to: accept responsibility for their own learning; trust their own thinking, recognize that there might be different views of similar events; realize that conceptualization of a problem depends on one's experiences with the issue; look for consistency or generalizability in constructing new knowledge or ideas; and realize that understanding

should be the goal of learning.

The Nature of a Constructivist Paradigm

People in education seem to be quite taken in recent years by the term "constructivism." For example:

- Philosophers describe "constructivism" as an attempt (among many other attempts) to reflect on and formulate an answer to the question that philosophers have put to themselves for millennia as they struggle to understand how we come to know what we know;
- Cognitive psychologists and educational researchers describe "constructivism" in terms of human learning theory and teaching theory respectively;
- Teacher organizations like the NCTM (National Council of Teachers of Mathematics) and NSTA (National Science Teachers Association) call for "constructivist" standards based on construction of learner-generated solutions and algorithms as more important than memorizing procedures and using them to get the right answer; or in the case of science instruction, reform based on "hands-on" and "minds-on" instructional techniques;
- Individual school administrators adopt "constructivism" as a guiding principle for curriculum reform within the respective districts or schools; and
- Individual classroom teachers operating from a "constructivist" pedagogy encourage and accept student autonomy, create educational environments in which students current thinking about specific content serves as the primary source of investigation and drives lessons, and value student metaconceptual and metacognitive dialogue, inquiry, and puzzlement.

In the above instances, "constructivism" is presumed to be a good thing whatever it is. With so many versions of constructivism currently in use (Good, 1993) it is likely that one person's version of "constructivism" may differ significantly from another person's version. Our main point her is not to either defend or attack a specific version of constructivism; rather, it is to stress the importance of in depth discussions that have the potential to result in new constructions of awareness and understanding of important, complex issues underpinning any paradigm, constructivist or otherwise. In the following section, we want to contribute to that dialogue by inquiring into the root assumptions of a constructivist paradigm, namely, by raising notions about the nature of a constructivist paradigm.

Aletta Zietsman

The title of this paper suggests that "constructivism" may have acquired interpretations and practices, that are pedagogically unsound. I believe that unreasonable expectations from a teaching community wanting fully developed "constructivist teaching packages" somehow to be delivered by "constructivism," lead to this. In addition, writers glibly deal with a complex and radical theory in statements such as

"constructivism means the learner is actively constructing his own knowledge". To me, this statement says nothing that could possibly influence traditional educational practices, and does not say much about the writer / researcher / teacher's views of learning and teaching.

It is as an epistemology, which I call my "ground zero" as a teacher, that radical constructivism holds most of its power for me. To me, the meaning of a student's "active construction of his own knowledge" resides in my understanding of "objective truths," and the concepts that Glasersfeld and Piaget have contributed, namely viability and adaptation. Glasersfeld describes (from the history of philosophy) a huge effort to get around a "root paradox" (Glasersfeld, 1993). The paradox is simple: a learner is expected to produce for herself a true representation of a real world. This is a paradox because any access that she has to the world is gained through an act of knowing, through activities of her own and hence there is no way of knowing to what extent she manages, modifies or invents the representation that is being constructed.

Piaget's genius is in his insight that the concept of knowledge as it existed in philosophy, must be changed. If knowledge has not worked logically in the way people have been thinking about it, then why not change the concept of knowledge? He suggested that knowing be viewed as an adaptive function in the basic biological sense. That is, for an individual to find ways and means of surviving with his knowledge and of maintaining his own conceptual balance. What are the consequences of this idea? Suppose that you are given the possibility of establishing a new relationship between knowledge and the reality which you presume frames all your doing and thinking. You have found a way of surviving within the constraints that living in the world have set up for you. Adaptation does not state that you are going to get a picture, or a true representation of the constraints - it merely means that you have found a way of working with them.

There remains the problem of "truths", however. That is, the idea that there exist "true representations" which all learners must eventually acquire (via adaptation and equilibration). But since there is no way of knowing what each person's "true representation" is, we are back to the paradox. Glasersfeld's (1987, 1992) concept of viability resolves this problem. He proposes to replace the concept of ontological truth with the concept of viability. Viability of knowledge simply asks whether a way of acting or thinking is viable to a person in such a way that it does not lead the person into obstructions or leads

him past the obstructions. Viability of a conceptual operation is much more complex: not only does the operation have to do what a person expects it to do, but ultimately it must not be in contradiction with other existing operations that are already being used. What you are requiring is coherence in the conceptual world. Here the interaction between adaptation and viability becomes clear: one does not want to have a conceptual world in which one has multiple conceptual models for similar problems and then find that the conceptual models are mutually contradictory. That is a disequilibration, and requires an adaptation of the knowledge - because it is not viable any more.

To summarize: To me constructivism is essentially a theory of knowledge. That is, a theory about the origin, nature and limits of human knowledge. It seems logical to me that one cannot begin to think about education without some theory of knowledge. Such beliefs underpin theories of learning and teaching. Yet, as Candy (1991) points out, it is rare to find theorists of learning and teaching who state their theories of knowledge explicitly. The reader is left to "infer the theory of knowledge on which the various formulations of learning are based" (Candy, 1991:262).

Clearly there is much more than "a learner constructing her own knowledge" at issue. At the heart of the implications of constructivism for teaching and learning are two radical ideas. First: the idea that we cannot know an ontological reality. Knowledge is therefore neither a copy nor a mirror of reality, but the forms and content of knowledge are constructed by the one who experiences it (Candy, 1991). All knowledge in use is being used because the user finds it viable, not because the "world out there is like that". And second, that the learner is ultimately responsible for his knowledge, for the world in which he lives. These are radical orientations, because there are no half-measures or piecemeal changes possible. The best analogy I can find is with sexism or racism: one cannot sometimes believe a little bit that a person of a different sex, or different race, is not quite your equal. So it is with constructivism: I cannot subscribe to a view of knowledge acquisition as a mapping of reality, or the production of true representations of the real world out there on the rare occasions that it suits me. For example, personally, as a teacher who holds a constructivist epistemology, I cannot entertain the practice of rote-learning, even multiplication tables.

The view of responsibility for one's knowledge is radical too. As a teacher I instinctively act as a nurturer, and perhaps even, unconsciously, regard students as not quite up to the task of knowledge

acquisition - they cannot learn without my revealing facts to them. To me this is an inhibiting view. In contrast, constructivism's core notions of viability and adaptation require reflection and choice, hence freedom to find alternative conceptions. This implies that any person can be an autonomous learner. Does this mean that a teacher should leave students alone, since they can potentially do it themselves? No, but one can conclude that constructivism suggests that teachers "create situations in which learners could develop and exert their innate drive towards acting independently" (Candy, 1991:258).

Michael Beeth

Labeling teaching and learning as constructivist captivates the science education community. Teachers and researchers routinely describe what they do as reflecting a constructivist paradigm or, at the very least, in keeping with a constructivist view of knowledge. However, what counts as constructed knowledge in science from a constructivist perspective and how this form of learning differs from more traditional forms is not at all clear.

Knowledge construction occurs at two distinct levels (Matthews,1993; Strike, 1987; Wheatley, 1991). First, the notion that students construct knowledge from their experiences. This assertion is typically accepted without question by science educators. It is during the experiential component of learning that material objects and phenomena in the natural world become known the learner. Organizing and categorizing these experiences occurs at the second level. At this level, learners adapt their sensory impressions to produce theoretical constructs that frequently ignore some of the experiences they just worked so hard to construct.

It is critical that teachers address the difference between knowledge that describes some real thing and knowledge that can be applied to classes of (somewhat) imaginary things. Teachers need to address this difference through their instruction in order to facilitate a deep understanding of the intellectual nature of science. The implications of this are that teachers need a framework for helping students learn to think about their thoughts as well as with their thoughts. This framework, or paradigm if you like, needs to include a sound understanding of the different forms of knowledge construction outlined above. It is this abstract nature of how scientific knowledge is constructed that makes it so difficult to communicate to learners. Matthews (1994) recognizes this as a critical problem with many constructivist approaches to

learning science--self identified constructivist approaches to learning retain an empiricist view of knowledge in that the scientific ideas are a reflection of an ontological reality.

For example, although living organisms have discernible physical and behavioral characteristics, no amount of observation will reveal the 'natural categories' into which living creatures are classified. There are no observable natural classes of living organisms, just groups of organisms that someone placed together for reasons that were meaningful to them at the time. Both inductive and deductive reasoning have be applied to classification schemes by scientists and students. The point is that classification schemes are an abstraction of human experience. Whereas objects in the material world have an ontological reality, objects of cognition do not. Science progresses through countless examples similar to the one described above.

Describing the attributes of physical objects and events in the natural world is fundamental activity for scientists. The scientific community has long established traditions regarding what counts or does not count as knowledge about theoretical entities (e.g., an epistemology of science) while students learning science concepts do not. Students learning science frequently express thoughts that are pragmatic, anthropomorphic, and, at times, irrational. The distinction between observing (re-sensing) the world and thinking in abstract terms places different demands on the construction of knowledge. Learners must think about and act upon metaconceptual and metacognitive constructs (Thorley, 1990). The constructs in this case are thoughts, ideas, concepts, and relationships. Knowledge is constructed in this instance in accordance with the viability that knowledge has for the learner and is not expected to be in total agreement with contemporary views on a particular topic.

Three decades of research on students' conceptions verify that alternative ideas to those of contemporary science do exist (Duit, 1993). In spite of this fact, a pragmatic consideration for teachers and researchers alike is that canonical views of the scientific community (e.g., facts, theories, laws, algorithms, etc.) continue to dominate science curricula. Students observe the natural world, describe objects and phenomena, perform laboratory investigations, and report the results of their inquiry. The cognitive demand placed on students during typical instruction is not one of dealing with their own thoughts about the natural world. They merely describe objects and phenomena for the teacher. Including issues concerning the nature of science (i.e., history, philosophy, sociology, and psychology of science) could improve students'

understandings of how scientific knowledge is produced and justified (Matthews, 1994). From a constructivist perspective, it is crucial that teachers begin to address this theoretical nature of scientific knowledge.

As defined here, instruction intending to facilitate the construction of knowledge (i.e., a constructivist pedagogy) has major pedagogical implications for what takes place in the classroom between teacher and students. When faced with the surface notion of constructivist pedagogy (i.e., that students construct knowledge from their experience) many teachers believe some aspects of their current efforts reflect the ideas associated with the construction of knowledge by learners. Teachers seem to readily accept the idea that students' ideas need to be addressed during instruction. Likewise, the notion of having student's understand science content at a deeper level is universally attractive to teachers at all levels. However, suggesting that the teacher might need to change her views on what knowledge is, and the consequences this view has for how she presents instruction, is not readily embrace by teachers.

M. Gertrude Hennessey

In lieu of directly addressing the nature of a constructivist paradigm, I would like to raise the issue of a need for more consistent forms of structural analysis to emerge among philosophers of science, cognitive science, and science education that more readily stimulate effective communication. By this statement I am not suggesting that as a body of philosophers we should strive to arrive at a consensus about the nature of reality, the nature of knowledge development, or what counts as the rules for the conduct of inquiry. I argue that this would be problematic because in accepting a given theoretical foundation--constructivism in this case-- without critically interrogating its underlying assumptions, is to become bound by that theory's metatheoretical assumptions (O'Laughlin, 1992). We need diversity of views --claims as divergent as Strike (1987), von Glasersfeld (1987, 1992), Matthews (1992), Suchting (1992), Vygotsky (1986), Driver (1983, 1989), and Driver and Bell (1985) to mention but a few--to provide the base for validating a genuinely emancipatory form of pedagogy. With respect to critical analysis, I think, the call for a more consistent form of structure to emerge can be better understood if we first take a look at the tools that enable us as philosophers to carry out the work of analysis of a specific paradigm: tools that are partly inherited and partly of our own making.

Tools of Analysis: Discontinuity, Displacement, Transformation

The disciplines that we call the history of ideas, the history of science, the history of philosophy, and the history of thought (we can ignore their specificity for the moment) attention has been turned away from vast utilities like "periods" or "centuries" to the phenomena of discontinuity, displacement, and transformation. I believe that historians of the above mentioned disciplines are now trying to detect incidents of interruptions: interruptions whose status and nature vary considerably. For example, the history of philosophy is replete with epistemological thresholds: they suspend the continuous accumulation of knowledge, interrupt its slow development, and force it to enter a new time, cut it off from its ontological or epistemological origin. In other words, there are displacements and transformations of paradigms: they show that the history of a paradigm is not wholly and entirely that of its progressive refinement, its continuously increasing rationality but that of successive rules of use, that of many theoretical contexts in which it developed and matured. The most radical discontinuities are the breaks effected by a work of theoretical transformation which establishes a paradigm by detaching it from the ideology of its past and by revealing this past as ideological. The problem presented by such an analysis is no longer one of tradition, of tracing a line, but one of division, of limits; it is no longer one of lasting foundations, but one of transformations that serve as new foundations, the rebuilding of foundations. In short, the history of thought, of knowledge, of philosophy, seems to be seeking, and perceiving, more and more discontinuities: what is missing at present, I believe, is a way of analyzing discontinuities once perceived.

With regards to analysis, what one is seeing, then, is the emergence of a whole field of questions, some of which are familiar, by which a emergent paradigm is analyzed as it develops into transformed theory:

- How is one to specify the different concepts that enable us to conceive of discontinuity (thresholds, ruptures, breaks, mutations, transformations)?
- By what criteria is one to isolate the developing paradigm with which one is dealing: it's ontological reality, epistemological, methodological? It's conceptual-theoretical nature and how it differentiates or corresponds with the nature of reality?
- What is legitimate level of formalization? What is that of interpretation? Of structural analysis? Of attributions of causality?

With regards to the constructivist paradigm, until a form of analysis emerges that stimulates understanding

and effective communication it is unproductive, from my perspective, to ask: What is the specific nature of the emerging constructivist paradigm? How is the emerging paradigm linked to past paradigms? How does the constructivist paradigm compare or contrast with alternate paradigms? Rather, with respect to the constructivist paradigm, it may be more effective to analyze the transformations that have the potential to occur as a result of recognized discontinuities.

A Constructivist Pedagogy: Implications for Teaching-Learning

Over the last fifteen years, the underlying assumptions about what it means to learn and to teach science have changed dramatically. Such as change, it is safe to say, principally have come about due to changes in perspectives on the:

- Nature and structure of scientific knowledge (as defined by philosophers);
- Effect a learner's prior knowledge has on subsequent learning (as defined by researchers in science education);
- Process by which learners develop the cognitive abilities through the process of progressively changing conceptual schemes (as defined by cognitive psychologists and researchers in science education); and
- Methods associated with the development of science knowledge (as defined by curriculum developers).

The shift in views of learning stemming from the above changes in perspective has lead to the development of new models of learning that: (a) recognize the importance of learner's existing knowledge in affecting how they learn; (b) describe the way in which learners incorporate new conceptions into their current knowledge structures; and (3) describe the way in which learners replace conceptions which have become dysfunctional. Increasingly, attempts by members of the science education research community to integrate and relate specific theoretical perspectives to real classrooms have lead to a series of prescriptions that have implications for pedagogical practice. At the curriculum level, the focus tends to be on a teaching sequences. Examples of curricula that employ specific sequences for teaching science to school age learners include: the learning cycles of explore, invent, and apply (Champagne, 1988); the generative learning model with focus on challenge, and application activities (Osborne & Wittrock 1983; Osborne & Freyberg, 1985); and the CLISP sequence of orientation, elicitation, restructuring, application and review (Driver & Oldham, 1986). The issue we wish to raise in this discussion is not whether the above mentioned curriculum are

representative of teaching-learning schemes, materials, and integrated topics, that have the potential to help students develop a conceptual understanding of selected science topics; rather, we wish to raise the issue as to whether significant changes in the teaching-learning process (a pedagogical reform so to speak) can begin with curriculum *per se*.

Michael Beeth

A constructivist perspective of knowledge development has multiple implications for teaching and learning. Foremost among these implications is the idea that teaching for conceptual understanding needs to be rooted in a particular view of how students learn (Hewson, Beeth, & Thorley, in press). This implication is one for the teacher, not the student. Although much of the research in the field of students' conceptions has focused on what students do not know, there is a growing concern with the knowledge teachers do or do not have about students' conceptions (personal communication with H. Schmidt, March 25, 1996).

Teaching for conceptual understanding places demands on teachers that change what and how they teach. Although teachers can use techniques associated with conceptual change teaching, such as the elicitation of students' ideas (Hewson, & Hewson, 1988), the question that immediately follows is: what do I do now that I know what the students' think? Do I let them muck around in their ideas for a while and then tell them the canonical view of science? Do I slow the pace of instruction so that all students have adequate time to work through their ideas? What are the conceptual issues that seem to be inhibiting knowledge development? How much time should I devote to issues not directly related to science content? Addressing students' ideas in the classroom requires a commitment on the part of the teacher to relinquish some control of the content in favor of facilitating construction of knowledge about scientific thought for the student (Beeth, 1993). Knowledge about scientific thought might include issues in the nature of science such as epistemological commitments and metaphysical beliefs accepted by the scientific community.

This is not meant to imply that a teacher disregard the other forms of knowledge important to teaching. Shulman's (1986) notions of content knowledge, pedagogical content knowledge and curricular knowledge still apply in classroom devoted to constructivist teaching and learning. Science teachers need to be well founded in science content. However, the demands of constructivist teaching imply additional

attention to issues in the development of particular science concepts as the thinking of many students seems to reflect historically important ideas on a topic. How the validity of knowledge claims are judged is at the heart of constructivist teaching. At some point during instruction it is important for a teacher to help students see not only their own criteria for the justification of knowledge but those of the science community as well.

The construct of pedagogical content knowledge is also a critical component of teaching from a constructivist perspective. Examination of your own ideas is often a difficult and sometimes distasteful task (I speak from personal experience here.). Engaging in the cognitive and metacognitive activities necessary for conceptual change is also not something that students readily accept as part of their schooling experience (see White & Gunstone, 1989). Students quickly learn to play whatever games gain them favor with the teacher and the grade they think they deserve. Students in constructivist classroom need to adopt a different attitude towards their success as a learner. What is important in constructivist teaching is the ability of the student to reflect on and communicate their ideas as a regular part of instruction. Success here is not measured by an external examination of facts but by a willingness to engage in these activities. Motivating students to engage in constructing their own knowledge should not be taken lightly. Pintrich, Marx, and Boyle (1993) rightly point out the need to address motivational constructs when attempting to teach for conceptual understanding.

What the curriculum is in a classroom devoted to constructivist teaching needs to be examined as well. The content of science can not just go away in order to deal with more philosophical issues of science. It can, however, be carefully selected and presented such that students are moved from merely describing real objects and events to working with their own ideas and the "theoretical objects" of science (Matthews, 1994). This change is significant in that the curriculum needs to include topics that do more than introduce students to additional content. The curriculum needs to respond to what the students are currently able to think about - both in terms of describing science content and in terms of knowing the limitations of their own thinking.

As recipients of a teacher's instruction, students respond to what the teacher demands of them in terms of cognition. If memorized facts and skills are demanded by the teacher, students respond by

memorizing facts and becoming proficient at performing skills. Constructivist learning pushes students to engage cogitatively as opposed to respond behaviorally. Teachers need to be able to access and evaluate students cognitive abilities. This is perhaps the most difficult aspect of constructivist teaching to describe since it relies on an established context with a student. Teachers need to constantly assess the status of students' ideas in order to evaluate if, and when, an idea changes (see Posner,Strike, Hewson & Gertzog, 1982). Even when ideas do not change, a student should be able to give reasons for holding on to their existing idea. The ability of students to describe what they do and do not understand about their thinking or about a science concept is what a teacher needs to evaluate. Frequently teachers express a type of intuition that tells them a student does or does not understand a concept in spite of the grade they received for a written evaluation. It is this kind of teacher intuition that needs to form the basis for evaluating students engaged in constructivist learning.

Finally, throughout the entire process of constructivist teaching there needs to be a mutually constructed climate of respect--respect for whomever is speaking and for what they have to say. Participating in constructivist learning requires risk taking on the part of the students. Seldom in during the process of schooling are students asked to share their thoughts about how knowledge comes to be in a discipline. This implication of constructivist teaching is one that separates it from behavioral and other forms of instruction. While constructivist teaching is more sensitive to what students do know, it comes with a potentially high psychological price for the student.

The above characterization of constructivist teaching implies new roles for the teacher, the learner, the curriculum, and what counts as evidence of successful learning. Most of the changes necessary to implement this form of instruction rest with the teacher. The most fundamental change for a teacher is that she think deeply about her epistemological beliefs concerning how knowledge is constructed and the implications this has for all aspects of her instruction. By itself, this is most likely to require a conceptual change for the teacher, the kind of change she is likely to ask of her students.

M. Gertrude Hennessey

The kind of sustained radical reform in science education, we as researchers and practitioners are calling for, is unlikely to take place unless we are willing to bring the implicit assumptions in which our

pedagogy is rooted to the surface so that we may subject them to critical interrogation. Examining one's own or another's pedagogical practices from an epistemological perspective is a difficult because it speaks to analyzing the underlying thinking and assumptions of the practitioner in question. I wish to avoid the notion that in do so, we will uncover the root causes of the problematic nature of teaching-learning process in which we all engage.

Our pedagogical practices, whether implicit or explicit, are tied to our personal claims about how people come to know. Coming to know, for proponents of a constructivism, is embedded in the many views of a constructivist epistemology. As Good (1993) has readily pointed out, there seems to be many flavors of constructivism: Piagetian, radical, social, socio-historical, postepistemological, pragmatic--to name but a few. Constructivist theory frames learning as an active, continuous process whereby learners draw on experiences from their environment to construct personal interpretations and meaning by using their existing knowledge to make sense of their new experiences. Moreover, learners actively construct knowledge by reflecting on their physical actions and mental constructs (metacognition) through social interaction with members of their learning community (Hennessey, 1993).

In school, however, the constructivist theory of teaching-learning is frequently mediated by the nature and goals of the learning activity, by norms and practice, and by the expected and accepted rules and roles of participation. Science teachers often feel obligated to ensure that students learn socially accepted knowledge (specific science content) from the learning activity. The perceived obligation often translates into a teacher participatory role of authority, which mitigates against students' collaborative construction of understanding. Thus, the action of many students are in response to what they perceive to be the appropriation of the teacher's agenda.

In the real world of school, there are no simplistic answers to the complex issue of teaching and learning at any educational level. We have all witnessed in this country many adherents to simple solutions--leaders who latch on to solutions such as the development of new curriculum (based on constructivist notions of teaching or otherwise), promotion of a national / state level curriculum, development of competency tests for both teachers and students, a call for statewide student performance testing, and recommendations for new organizational structures within schools. Unfortunately, as researchers and

professional educators, we are not immune to this failure. Our best hope for resisting this trend is to keep before us the full range that relevant scholarship has to offer. Whether our main scholarly interests be in cognitive development, constructivist approach to learning, curricula development, cooperative learning, or assessment of learning, we need to be continually aware of the full sweep of scholarship available to us and not simply seek one solution that will lead to marked improvement in education.

The Nature of "Pedagogical Tricks"

The three of us were first introduced to the term "pedagogical trick" by Reinders Duit. The term held such a fascination for us that we subsequently decided to probe Reinders' thinking as to the nature of the term. Excerpts from our e-mail conversation appears below; Reinders states:

> There is a personal history to the term [pedagogical trick]. When our nephews were young my wife and I often traveled with them...[during the trips] we tried our best to handle these young boys and used what they [the boys] called "pedgadogischer" trick...the original meaning [in this context] was quite clear: to lead the boys by some sort of verbal (or non-verbal) treatment to the kind of behaviour we [my wife and I] loved. To put it another way to lead the boys to a behavior we saw as the right one. Since then the term "pedagogischer" trick is part of our personal language game...[Reinders goes on to apply the term to a constructivist approach to learning.] In my opinion the constructivist view of learning, if taken serious has much more to offer than making science instruction simply more effective. Truly constructivist approaches aim at fundamental restructuring of science teaching and learning. We all have our visions [of constructivist practices]...and I think the visions we have as constructivists share many key facets...I use the term "pedagogical trick" to describe *a limited* constructivist approaches, that simply and solely aim at making science instruction more effective...a way of trying to bring old topics [science content] into the heads of students with new "pedagogical tricks"--a constructivist method [personal communication. 9 Feb, 1996].

The notion that, pedagogical practices could, under certain circumstances, be considered a form of trickery is for us a notion worthy of further discussion.

Michael Beeth

Pedagogical trickery is something I have spent a lot of time thinking about since the 1995 Annual Meeting. I must admit that never occurred to me I should consider trickery as part of what is broadly defined as teaching for conceptual change. To me, the notion of trickery includes the intent to deceive on the part of the trickster (e.g., a motive) and some amount of gullibility on the part of those being tricked. Just who is included in the categories of trickster and the tricked is not at all clear to me

In some sense, all forms of teacher lead instruction involve deception--if deception means intentionally withholding some parts of science in favor of presenting others. Some teachers readily admit

that 'covering the content' is the most important aspect of what they do as a teacher of science. Justification for this approach to science teaching generally includes some argument about preparing students to accept their future role in a scientific community. Other teachers choose to engage students in doing science and use science content as the context within which to learn the nature of science as an intellectual process. In a very general sense, teachers who adopt this approach hope to advance the level of scientific literacy in the population at large. Still another approach to learning science involves apprenticeship in some field of scientific study, such as an immersion experience working with practicing scientists. Teachers placing students in immersion experiences knowingly sacrifice breadth of coverage for the depth of involvement an individual students receives in a single topic.

Are each of these to be considered trickery? Certainly the motives of the teachers in cases like those above are apparent. Teachers do make choices in the selection and presentation of content. We all chose and present curriculum with which we feel comfortable. Many teach versions of what they learned while in college. My experience has been that teachers, myself included, always find room in the curriculum to include information on the most recent workshop or summer program they attended. I recently completed a Faculty Development Project on Gender Equity and my teaching reflects my participation in the project.

The hidden curricula presented by teachers is infinitely more difficult to discern. Personal values come into play when teachers chose to present content of a sensitive or controversial nature--the presentation of biological evolution being the primary example. However, there are many other times when personal values enter into science instruction. Teachers do address these issues, although not directly as in the case of what content to teach. What does a teacher do to acknowledge the lack of representation by women and people of color in science? How do you present issues in human reproduction? Can (should?) you encourage students to take political action on local issues such as pollution, the decision of an elected school board to provide science magnet schools or euthanasia?

Another form of trickery might occur when the teacher delivers content in a particular manner. If the teacher's instruction allows for only a single, scientifically correct answer then there is no trickery. That's right, there is no trickery. Students know how to play this game. The day before an exam students ask the teacher, "Do I have to know this?" or "What's going to be on the test tomorrow?" This is game playing on

the part of everyone involved and students are masters at this game. The teacher tells the students what they need to do to pass this class, not to understand science concepts in any meaningful way. The goal of instruction is the accumulation of enough points by correctly stating facts in a manner acceptable to the teacher.

Teaching that is driven by a view of learning as conceptual change does not follow a similar pattern to that immediately above. Here the role of the teacher shift to that of facilitating the development of students' ideas. Students' ideas are taken to include knowledge about the content of science and knowledge about their ability to learn science. The reasons and justifications that support the construction of knowledge claims are dramatically different goal of instruction when teaching for conceptual change. Another goal of instruction is recognition of the utility of an idea. Some ideas, indeed many, may be barely comprehensible. Others may be fruitful (in the words of Posner et al.) and serve to open up new avenues of inquiry for the learner. Significant issues in the view of knowledge construction alluded to here can be found elsewhere in this paper. The goal of learning here is not the achievement of a grade as much as it is helping the students come to know themselves in the context of learning science.

Students of course do not immediately accepts instruction based on principles of conceptual change. Pintrich, Marx and Boyle (1993), in reference to the overly rational view of knowledge contained in the Conceptual Change Model of Posner et al. (1982), called attention to the need to motivate students to participate in this form of learning. The statements below, taken from White and Gunstone (1989), clearly indicate the resistance some students feel toward participating in the kind of thinking necessary for conceptual change:

> S1: 'We see what all of this is about now,' one said. 'You are trying to get us to think and learn for ourselves.'
>
> T: 'Yes, yes.' replied the teacher, heartened by this long-delayed breakthrough, 'that's it exactly.'
>
> S2: 'Well,' said the [second] student, 'we don't want to do that.'

Is it trickery if teachers immerse students in conceptual change instruction without consulting them? Yes. The demands of learning are considerably different from traditional instruction and students need to know what they will face when confronted by their own thoughts and ideas. Progress in learning is slow

at best in these classrooms and students can become disenfranchised with the process. In addition, there are times when confusion and confounding of some issue are what happens for several days. Most of us, students and teachers, are not comfortable when we don't accomplish what was planned for a particular day. I have seen teachers using principles of conceptual change spend inordinate amounts of time on what seemed a rather minor issues (i.e., the status concepts of intelligibility and plausibility). However, when these students needed to make distinctions regarding the status of an ideas they did so without reservation (Beeth, 1995).

Students are seldom allowed to truly chose the curriculum they will study. However, in a conceptual change classroom they already have the curriculum--it is the ideas they bring to the classroom. Teachers facilitate further development of those ideas by how they respond to the students' ideas and what they demand of students in a cognitive sense. Although it is not possible to prescribe what or how to teach in this case, the roles of the teacher and the students' are vastly different from more traditional forms of instruction.

Trickery could also occur when we, teachers and researchers, accept statements from students that we believe represent a change in conception. Granted what counts as evidence for conceptual change and at what age this form of instruction would be appropriate are questions open for discussion. Principles stemming from psychological theories, most notably the work of Piaget, disallow abstract reasoning at particular developmental stages.

Aletta Zietsman

To enable a discussion of pedagogical "tricks", one needs to establish what an epistemology would be for any ordinary teacher. I have often heard the lament from teachers "But HOW can I be a constructivist teacher? It sounds wonderful, so what should I do?" This plea for help contains the essence of the "constructivist teaching issues:" no-one can tell a teacher "what to do" - as von Glasersfeld says, but one can tell teachers a whole lot of things NOT to do. Unfortunately, such advice is not likely to inspire people to deep epistemological reforms.

I believe that one has to be very explicit about a personal epistemology to be able to proceed with the debate. However, many teachers are shocked by the idea that an epistemology is required. What is it? Often the word is heard for the first time. Rather than asking such "jargon" laden questions, perhaps we should ask teachers to write down:

- How do I teach (not a topic) but in general: e.g. what does my classroom look like, what do the students DO in my classroom, what is forbidden in my classroom?
- What do I mean by successful teaching?
- What do I mean by successful learning?
- Does a. help me to attain in some way b. and c.?

Implicit in the answers above is the teacher's view of knowledge as well as how that view translates into her teaching practice. It is my believe that any teaching practice which violates a teacher's epistemology would amount to trickery. I have personal experiences of beautiful, "constructivist" materials, developed by experts who work from a constructivist perspective. The research base for these teaching/learning materials was impeccable: all possible clients were included in all research and development phases. Yet in almost all the classrooms where these material were used, the education amounted to pedagogical trickery. The reason should be obvious, and it is at the same time one of the central tenets of constructivism. The intentions, the knowledge, the values implicit in the materials were "from the outside" so to speak. Certainly the teacher's existing epistemology (as evident in her teaching practice) was more viable that the new practice suggested (or even imposed) on her. How then can one expect more than "trickery"? Situations where the teacher is being "less than truthful" in trying to bend her practice to "fit" the new curriculum?

I am strongly suggesting that, without a commitment to constructivist epistemology from the teacher, all pedagogical activities that purport to be constructivist, could be regarded as trickery.

What then is a pedagogy grounded in constructivist ideas? What does it look like? Obviously, as a result of the central tenets of constructivism, I can only relate what MY personal construction of such a practice would be. To be able to have a reference point, a baseline of what is unacceptable, I start by comparing epistemologies. First, I state my view of what I regard as the predominant theory of knowledge that underpins most of current educational praxis: Knowledge is viewed as an accumulated body of true facts, verified by observation and experimentation. The truths are about an independent world that is real:

a reality that exists by itself and in itself (Glasersfeld, 1987). How does this view determine a teacher's view of learning and teaching? To me it means that a teacher reveals the facts to students, who produce for themselves true representations of these realities. Or if you want, teaching is telling and learning is remembering. How many times have we all heard (and expressed!) the lament "But I TOLD them" when students get "it wrong" in an exam or test. To me such a statement clearly suggests a view of teaching and learning as telling and remembering.

Second, my view of a teaching practice grounded in constructivism has the following characteristics: rather than "telling and remembering", the view of knowledge suggested by radical constructivism is expressed succinctly by an often cited phrase from Piaget: "Intelligence organizes the world by organizing itself". Thus, the human being is, from birth, constantly engaged in the processes of adaptation of knowledge, trying to establish "conceptual coherence". Human knowledge does not consist of real, true facts, but is viewed as knowledge that is viable to the individual in making his way in the world. A teacher with such a theory of knowledge does not reveal facts to the students, but creates opportunities for students to test "whether their construing of situations adequately accounts for what they see, hear and experience" (Candy, 1991).

To me there is much more than "a learner constructing her own knowledge" at issue: there are numerous interactions with the world (objects, people) from which the almost fragile, and never complete, knowledge is continually being adapted so that it remains viable to the individual. As stated above: constructivism's core notions of viability and adaptation require reflection and choice, but also important are the constraints of culture, community and environment, to mention a few.

Implicit in the pedagogical practice of a constructivist is the central notion that the students must also develop an epistemology. The truths of the community to which we belong appear to tell us how the world is, not how it ought to be. It is a fact of constructivist practices that we are typically challenged by another member of our community if our actions are not in accord with accepted truths. If our actions continue to conflict with a truth and we cannot justify our conduct in a way that satisfies the standards of argumentation of the community, we eventually cease to be members of that community. Thus, in this view, members of a community interactively constitute the truths that constrain their individual activities. (Cobb,

1992) In this way, we all learn and develop - by argument, explanation, justification - as any sophisticated scientific research community would. Anything less that this would be pedagogical trickery.

This is why I regard a teacher's theory of knowing as "round zero". It is from this baseline that one proceeds as a teacher. Your epistemology determines your view of the learner, how you develop instruction, how you organize your classroom. It DOES NOT say how to go about those actions: it pre-determines them. In a sense the theory tells you what not to do, just as your beliefs about gender, race and equality will determine how not to behave.

M. Gertrude Hennessey

The notion that my personal pedagogical practices could, under certain circumstances, be considered a form of "educational disservice" to those I intent to serve is a notion that I have struggled with for many years. Until last year I lacked a form of meaningful terminology to describe this puzzlement. Thus, when the term "pedagogical trick" was introduced into a general discussion about classroom practices, naturally, I was more than curious. The standard dictionary definition of "trick" includes elements of employing a device or an action designed to achieve an end by deceptive or fraudulent means, stratagem, or rouse. The definition, when applied to the teaching-learning process, is premised on the assumptive relationship between achieving the desired end (in this case, learning) and methods chosen (pedagogical practices) with the intent to deceive (someone). Laying aside the issue of "willful intent to deceive," (it would be presumptions on my part to make claims about the intent of anyone other than my myself), I would argue for the existence of multiple levels of "trickery" in educational practices.

Who, What, and How?

As I began to write my comments for this section of the paper, questions bearing on issues of authority, culture, and power in the classroom came to mind: *Who* decides on *what* pedagogical practices, curricular content, and kinds of discourse are permissible within the classroom and in *whose* interest? *How* are those we wish to influence the most affected by these decisions?

My response to the question of: *Who* decides? is relatively straight forward--those in authority. The conclusion is inescapable that to the degree that the teaching-learning process does not problematize the voice of authority inherent in classroom pedagogy, text, and practices, both teachers and students will learn

that their voices are not valued, and that school is not a place in which genuine construction, co-construction, and re-construction of knowledge and meaning is valued. They will also learn that the voice of authority, whether researcher, curriculum developer, administrator, teacher, or text, is privileged and authoritative.

Another key issue is defining: *Who* is "tricked;" and by *whom?* By way of contrast, the concept of "pedagogical trickery" has the potential to occur at multiple levels within the educational setting: researchers and curriculum developers tricking practitioners, teachers tricking students, students tricking teachers; namely, any stakeholder in the educational enterprise is subject to trickery by any other stakeholder. Consider the following vignettes:

- Learners treating lesson as rituals to be followed in order to please the teacher and play the game of school; typically by making judgements and offering opinions that are in accord with what they perceive to be the teacher's expectations.
- Learning environments in which students' freedom to introduce their own ideas is largely illusory; that is, the teacher retains a strict control over what is said and done, what decisions are reached, and what interpretations are put upon classroom experiences.
- Teachers planning activities, lessons, labs, projects that have a predetermined purpose, namely, to acquire information that has been predetermined for the student by the teacher or text; so that the ideas that students must arrive at from their experiences are actually preordained.
- Learners actively constructing their understanding when it is obvious the teacher knows all the answers, appears to ask all the questions and does his or her best to provide the answers via an alternative mode of teaching.
- School administrator providing new materials to practitioners who lack the epistemological underpinning to effectively implement the curricular materials in a manning meaningful to their students.

All of the above vignettes, in my opinion, are illustrative of the nature of "pedagogical trickery" because the voices and interests of some groups are privilege at the expense of others; and because there seems to be a lack of genuinely emancipatory communicative environment in which the individual stakeholders begin to construct meaning together on their own terms and in their own interests (Guba & Lincoln, 1989).

Ambivalent role of constructivism

The alternative to the authoritative discourse mentioned above is dialogue that occurs when the learner is influenced by experience, teacher, or text, but is also allowed the space and time to take an active role in the developing of personally constructed understanding of the topic under consideration through dialogic and metaconceptual interchange. A truly emergent curriculum would validate the ways of knowing

learners bring to the learning situation by grounding the curriculum in the learners' voices and lives. As Solomon (1992) notes, through dialogue and sharing of perspectives, learners will gradually come to see their own perspectives as one of many socially and historically constituted ways of knowing, and through exposure to multiple voices learners could begin to engage other perspectives and other ways of knowing, thus enlarging their epistemological perspectives.

Another question that comes to mind is: *How* have we, as members of the research community in science education, added another dimension to the nature of "pedagogical trickery?" Current prescriptions stemming from our research perspectives do not necessarily differentiate between the ontological, epistemological, and methodological levels underlying our research practices. The fatal flaw in this practice is that frequently the ontological and epistemological posture of an argument becomes lost at the level of practice. For example, researchers who develop new curricula based on their research pursued their work from a specific paradigmatic stance. These curricular models of teaching make specific assumptions, often well articulated, about the role of the teacher and the dynamics of classroom instruction. It is my contention, however, that this paradigmatic stance is often lost as classroom teachers attempt to implement the curricula in question. When this paradigmatic loss occurs, instructional strategies or teaching sequences that were initially designed to address (1) the nature of reality (what there is that can be known), and (2) the dynamic nature of knowledge construction (the relationship between the knower to the known) can, in fact, become a mere set of practices or behaviors to be adopted. It is my stance that when one set of behaviors (stemming from a objectivist or any other paradigm) is replaced with another set of behaviors (stemming from a constructivist paradigm) we should begin to question the nature of this exchange. The challenge, then, for researchers, curriculum developers, and practitioners is how best to integrate both the ontological and epistemological stance underlying the development of curricula with the methodological prescriptions for practice--thus, avoiding a potential set of "pedagogical tricks."

A counterargument can be made by asserting that paradigms are distinguishable only at the level of methods, that is, as mere collection of different inquiry tools and techniques. Proponents of this counterargument assert that while there may be quite meaningful difference at the ontological and epistemological levels, these differences do not matter in the day to day workings of a complex educational

environment. At the level of practice, practitioners find it impossible to deal with the ontological and epistemological levels. Instead they opt for a set of teaching sequences (methodological level) that have the potential to address student thinking. Whether this set of teaching practices can be considered a set of "pedagogical tricks" is not an issue in this instance. The primary focus is having the students resonate with the teacher's plan--i.e., it seems "important that the students should understand and share with the teacher the goals of learning, being introduced to the rules of the game as they play (Hewson, et al 1995)."

Closing Discussion

Because the purpose of this paper is to act as a thinking device to generate dialogue, it would be contradictory to our purpose to conclude with some definitive remarks that tie the issues raised in the paper up nearly and left not room for further dialogue. As the last paragraph is being written, the question "Who is being tricked by our pedagogical practices, by whom, and for what purpose?" reverberates as the most essential question to be addressed by educators. Frequently the voices of those we wish to most influence can provide the best answer. The only way to learn more about the effects of our current pedagogical practices is to start a dialogue *with* those we wish to educate. We must keep the perspective, however, that learners are experts on their own lives. There are certainly aspects of the teaching-learning process of which they may not be aware, but they can be the only authentic chroniclers of their own educational experiences. We must not be two quick to deny their interpretations of our pedagogical practices, or accuse them of false understanding. The following short essay written by a twelve year old commenting on her perceptions of the teaching-learning process best expresses the kind of invitation to dialogue that we would like to see academic researchers extent to science teachers, and that we would like to see science teachers, in turn, extend to their students:

> I think learning in science is about wondering about the world, how it works, and then asking yourself questions that you find challenging.
>
> I think a good analogy for learning is a puzzle. You can have all 1000 pieces but if you don't take the time to fit them together you will never see the picture. Most school learning [is] like collecting the pieces of the puzzle and keeping them in a box. Teachers reward you for collecting enough pieces, the more pieces you collect the better the rewards your receive. I think learning in science class, however, is much different. Back to my analogy of the puzzle. In science class we spend a good bit of time trying to fit the pieces of the puzzle together. Sometimes it takes all of us working together just to fit one piece of the puzzle into it right place in the picture. The analogy isn't perfect because there is only one way to fit the piece into the puzzle but in science there is much more than just one way to

fit science ideas together.

> To me learning is the work you do as you fit ideas together. Using your experiences, talking with other in class, building models that represent you ideas all help you think about how ideas fit together. And that, I think makes for good learning [Project META, grade 6, 1993-94].

Finally, as academic researchers, we must be vulnerable enough to allow those we wish to influence the most to dialogue among us as *equals* in order to allow the realities of others to edge themselves in our consciousness.

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